
Edison Environmental Center


Portland, Oregon

National Risk Management Research Laboratory

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GREEN INFRASTRUCTURE RESEARCH PROGRAM

Providing Research Solutions to Manage Wet-Weather Flow

Rain Garden Hydrology

Introduction

Rain gardens are vegetated surface depressions, often located at low points in landscapes, designed to receive stormwater runoff from parking lots, roofs and roads. Typically constructed with sandy soils, the gardens allow stormwater to infiltrate quickly to underlying native soil and eventually contribute to groundwater recharge. Vegetation and soils within the rain garden remove stressors in stormwater runoff through biological and physical processes such as plant uptake and sorption to soil particles. Compared with stormwater release to receiving waters through conventional storm drains, infiltrating stormwater through rain gardens reduces peak flow rates and volumes with stressor loadings. This reduction improves the physical and biological integrity of receiving streams by reducing stream bank erosion and negative effects on aquatic communities.

Background

The National Risk Management Research Laboratory (NRMRL) is evaluating rain gardens as part of a larger collection of long-term research examining multiple stormwater management practices. The U.S. EPA recognizes the potential of rain gardens as a green infrastructure management tool to lessen the effects of peak flows on aquatic resources. While local governments and individual homeowners are building many of these systems, relatively few studies have quantified rain gardens' ability to infiltrate stormwater to groundwater, thereby reducing peak flows.

Objectives

The Green Infrastructure Research Program's long-term rain garden research addresses two objectives to meet these challenges:

- Quantify the hydrologic performance of rain gardens accepting parking lot and roof runoff and changes with season and rain garden age.
- Test multiple ratios of impervious surface area to rain garden area in terms of hydrologic performance.

Experimental Approach

Controlled-condition research enables NRMRL investigators to collect high-quality information. Collecting data and performing experiments at field sites away from the laboratory limits research due to uncertainties in weather forecasts, site access, utility locations, vandalism, and other logistical issues that collectively add greatly to the costs and timelines of research projects.

Using on-site, experimental rain gardens enables NRMRL to collect high-quality data necessary for evaluating engineered structures. The laboratory facilities and space available at the Edison Environmental Center also allow for construction and monitoring of functioning, full-scale rain gardens, producing data directly relevant to real world applications while avoiding unnecessary risks to people and equipment.

Research Background

Cities and towns across the nation are building or planning to install rain gardens to accept and infiltrate stormwater runoff from parking lots, roofs, and roads in high-density urban settings. Although hydrologic properties such as infiltration rates, surface ponding depths and duration, and overflow have been well-researched at the bench and pilot scale, few studies have been conducted in full-scale rain garden applications. As a result, current sizing criteria in federal and state rain garden manuals range between 5% and 50% of the impervious area draining to the rain garden (NC Coop. Ext. Serv., 2005; UW-Extension, 2003; U.S. EPA, 2009), leaving designers with little clear guidance when making decisions about rain garden sizing. This is a critical need given the importance of avoiding excessively long periods of flooding and overflow, particularly during the more common small- and moderately-sized storm events. The question of how large to make a rain garden in a given location relative to the impervious area draining to it takes on added significance in urban settings where land is expensive and highly valued for a variety of uses.

An additional area of uncertainty in full-scale rain gardens involves the mechanics of acquiring high-quality monitoring data. Previous experiences of EPA researchers and the wider scientific community have shown that green stormwater management practices like rain gardens and pervious parking lots must be designed with the capacity for long-term monitoring, as retroactively equipping an existing structure to collect monitoring data is impractical. In this study replicated rain garden cells are outfitted with buried instrumentation to collect long-term hydrologic data. This data will be analyzed to evaluate the effectiveness of the monitoring plan in terms of the location, number, and types of instruments employed as well as the measurement frequency, storage and analyses techniques.

Current Research

The schematic on the following page details the design of the rain garden cells located south of a newly-constructed green parking lot. The rain garden consists of six separate cells that are hydrologically isolated from each other using 3/8 inch-thick plastic sheeting installed to a depth of 4 feet (see figure on next page). The six cells receive stormwater runoff from an impervious section of the parking lot and adjoining sidewalk through curb cuts at the south end of the parking lot. Stormwater runoff from the roof of the adjacent building is collected from multiple downspouts and conveyed beneath the sidewalk in a common 8 inch-diameter pipe. A dedicated 4 inch-diameter pipe distributes the roof runoff upward into each rain garden cell just south of the curb cuts. The drainage area to all six cells is roughly equal (12,500 m^2), but because the rain gardens are different sizes, they represent different percentages of their drainage areas. The two smallest cells are 2%, the two medium-sized cells 4%, and the two largest cells are 8% of their drainage areas, respectively. Each cell size is duplicated for statistical purposes. All cells are equipped with soil water content reflectometers and thermistors (to measure soil moisture and temperature, respectively) at multiple depths in the soil profile at the north and south ends of each cell. A cluster of piezometers and wells at various depths is located in the center of each cell. All instrumentation contributes to quantifying the timing and size of the wetting front in the rain garden during and following storm events.

In addition to the rain gardens and associated pervious pavement parking lot, NRMRL operates the 20-acre Urban Watershed Research Facility that includes stormwater mesocosms, laboratories, greenhouses, fabrication space, a pipeline testing facility, swale and pervious parking lot performance testing, and storage for equipment and supplies. This unique facility is part of the larger 200-acre Edison Environmental Center operated by the U.S. EPA Region 2. This land area allows NRMRL to undertake research on a scale that cannot be executed at any other U.S. EPA facility. Additional rain garden research at the pilot-scale is ongoing at the research facility (U.S. EPA, 2008). This work focuses on stressor removal in rain garden media and vegetation.

Impacts

The successful application of bioretention and pervious pavement systems at the Edison Environmental Center's pervious pavement parking lot demonstration site, as determined by the results of the research and monitoring effort, will allow for technology transfer to other federal facilities and to municipalities considering adopting green infrastructure to alleviate CSO problems. A more complete understanding of how rain gardens function will enable the U.S. EPA to provide national guidelines on rain garden design, construction, maintenance, and monitoring which local organizations can use to reduce peak flows to receiving waters. Reducing stormwater peak flows will help maintain the function and integrity of aquatic resources. Rain gardens and other management tools will help watershed managers assure that receiving waters meet the "fishable and swimmable" goals that Congress outlined in the Clean Water Act and better assure the continuing supply of high-quality, potable water needed for human life.

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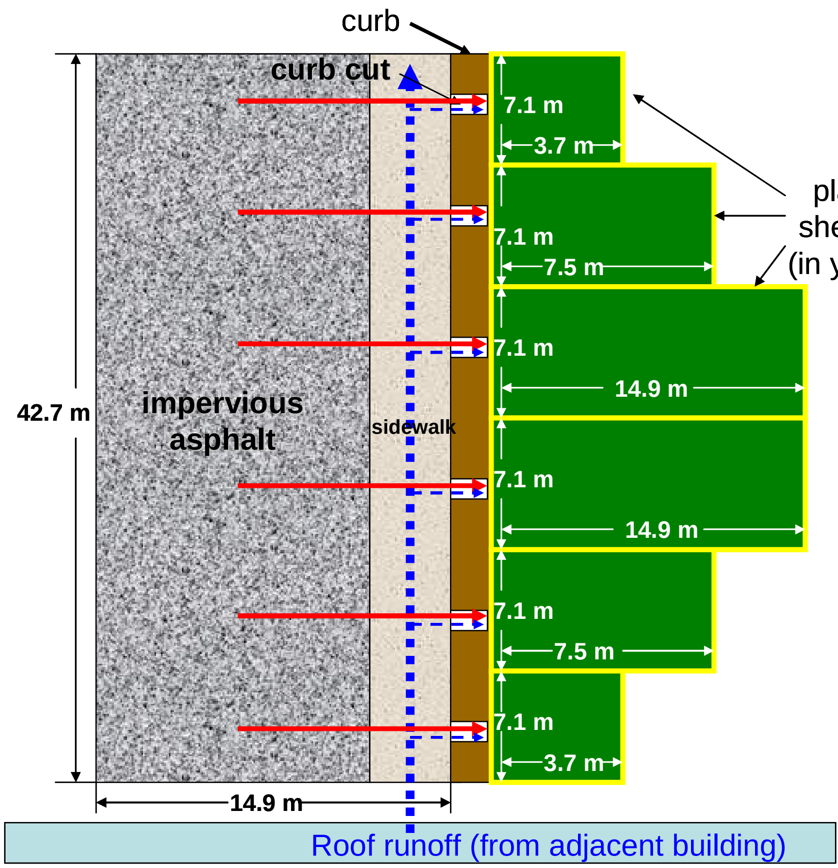

This schematic shows the rain garden cells (in green) located south of the impervious section and sidewalk associated with the newly-constructed parking lot. All rain garden cells are hydrologically isolated from each other; the yellow lines represent the plastic walls which separate the cells. All six cells receive stormwater runoff (represented by red arrows) from the impervious section of the parking lot through curb cuts. Stormwater runoff from the adjacent building is conveyed to the six rain garden cells through an underground pipe manifold system (represented by the dotted blue arrows).